Rochester Connectionist Papers: 1979-1985

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TR 172
December 1985

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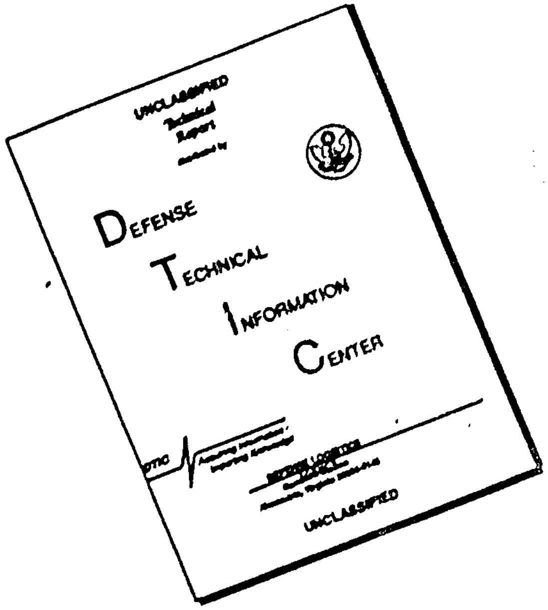

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This bibliographic listing of papers on computer topics covers the following:

1. Background Papers
2. Definitional Papers
3. Intrinsic Images and Visual Gestalts
4. General Vision
5. Applications to Natural Language
6. Speech Production
7. Motor Control
8. Knowledge Representation and Inference
9. Simulation
10. Hough Transform Developments
11. Theory

Appendix A: Errata Sheet for "Dynamic Connections in Neural Networks"

1. Background Papers

Ballard, D.H., "Generalizing the Hough transform to detect arbitrary shapes," *Pattern Recognition 13*, 2, 111-122, 1981.

A primordial paper which introduces generalized voting and the idea of voting to detect shape invariance.

K.R. Sloan, Jr. and D.H. Ballard, "Experience with the generalized Hough transform," TR 83, Computer Science Dept., U. Rochester, 1980; *DARPA Image Understanding Workshop*, College Park, MD, April 1980; *Proc., 5th International Pattern Recognition and Image Processing Conference*. Miami Beach, FL, December 1980.

Examples of the general shape recognition scheme in action. Subsequently, much more detailed experiments have been carried out at SRI International.

Feldman, J.A., "A connectionist model of visual memory," in G.E. Hinton and J.A. Anderson (Eds). *Parallel Models of Associative Memory*. Hillsdale, NJ: Lawrence Erlbaum Assoc., Publishers, 1981.

This is the first attempt at formulating what would now be called a localist connection model. Surprisingly enough, none of the informal discussion needs to be recanted (yet), and several topics discussed generally here have not yet received systematic treatment.

Feldman, J.A., "A distributed information processing model of visual memory," TR 52, Computer Science Dept., U. Rochester, December 1979.

A preliminary version of the above, which has no current value.

Feldman, J.A., "Connections: massive parallelism in natural and artificial intelligence," *BYTE Magazine*, April 1985.

A gentle introduction.

2. Definitional Papers

Feldman, J.A. and D.H. Ballard, "Connectionist models and their properties." *Cognitive Science* 6, 205-254, 1982.

The basic reference. It contains definitions, generally useful constructs, and a variety of examples.

Feldman, J.A. and D.H. Ballard, "Computing with connections," in A. Rosenfeld and J. Beck (Eds). *Human and Machine Vision.* New York: Academic Press, 1983.

This differs from the above mainly in the inclusion of an eigenvalue stability theorem for the special case of symmetric inhibitory-excitatory arrays.

Feldman, J.A. and D.H. Ballard. "Computing with connections," TR 72, Computer Science Dept., U. Rochester, 1981.

This is the draft from which the two above papers derive. It is much rougher and not to be believed. The one thing that has not appeared elsewhere is a detailed treatment of symmetric mutual inhibition (winner-take-all) networks.

Feldman, J.A., "Dynamic connections in neural networks," *Biological Cybernetics* 46, 27-39, 1982.

This is the basic reference for short- and long-term memory change, dynamic links, and recruiting of concept nodes. It is riddled with misprints; an errata sheet is Appendix A of this report.

Feldman, J.A., "Memory and change in connection networks," TR 96, Computer Science Dept., U. Rochester, December 1981.

The draft report for the article above. It contains a good deal of motivating discussion missing from the *Biological Cybernetics* piece, and more technical details in several places.

Feldman, J.A., "Energy and the behavior of connectionist models," TR 155, Computer Science Dept., U. Rochester, November 1985.

An introduction to and critique of formal methods for analyzing models, particularly energy methods and models.

3. Intrinsic Images and Visual Gestalts

Ballard, D.H., "Parameter networks," *Artificial Intelligence Journal 22*, 235-267, 1984. (An early version of this paper was presented at the *7th International Joint Conference on Artificial Intelligence*; a later revision is TR 75.)

The first paper which lays out a parameter-space theory of visual gestalts. This theory focuses on problems of computing intrinsic images and global organizations in patterns.

Ballard, D.H. and O.A. Kimball, "Rigid body motion from depth and optical flow," TR 70, Computer Science Dept., U. Rochester, 1981; *Computer Graphics and Image Processing 22*, Special Issue on Computer Vision, 95-115, 1983.

Shows how rigid body motion parameters can be detected from a depth map and optic flow field. Further elaboration of the subspaces concept.

Ballard, D.H., C.M. Brown, and O.A. Kimball, "Constraint interaction in shape-from-shading algorithms," *Proc., DARPA Image Understanding Workshop*, Palo Alto, CA, September 1982; *1982-83 Research Review*, Computer Science Dept., U. Rochester, 1982.

First demonstration of the concept of coupled computations, whereby a global parameter (sun angle) is estimated concurrently with surface normals via parallel-iterative Hough relaxation.

Ballard, D.H. and P.C. Coleman, "Cortical connections: Structure and function," *Workshop on Vision, Brain, and Cooperative Computation*, U. Mass., Amherst, May 1983; TR 133, Computer Science Dept., U. Rochester, January 1985; to appear in *The Behavioral and Brain Sciences*, March 1986.

Shows how unit-value concept (and others in [Feldman and Ballard, 1982]) constrains cortical anatomy. A basic position paper that, in the *BBS* version, contains valuable commentary from other research groups.

Stuth, B.H., D.H. Ballard, and C.M. Brown, "Boundary conditions in multiple intrinsic images," *Proc., 8th International Joint Conference on Artificial Intelligence*, Karlsruhe, Germany, August 1983.

Enunciates the continuing hope that multiple intrinsic images are easier to calculate together than separately. Several evocative examples but few new hard results. Not connectionist except for use of Hough transform.

4. General Vision

Feldman, J., "Four frames suffice: A provisionary model of vision and space." TR 99, Computer Science Dept., U. Rochester, September 1982; *The Behavioral and Brain Sciences 8*, 265-289, 1985.

An attempt to provide an account of the overall functioning of the visual system in connectionist terms. Three of the four coordinate frames are based on the eye, the head, and extra-personal space, while the fourth is general world knowledge and non-spatial. The model purports to be consistent with all behavioral, biological, and computational constraints. The accompanying commentary is illuminating.

Ballard, D.H. and D. Sabbah, "View-independent shape recognition," *IEEE Trans. on Pattern Analysis and Machine Intelligence 5*, 6, 653-660, November 1983. (Also appeared as TR 92, which has some minor bugs.)

Introduces the idea of detecting high-dimensional features by using subspaces. In the context of view transforms, rotation and scale are shown to be computable before translation.

Hrechanyk, L.M. and D.H. Ballard, "Viewframes: A connectionist model of form perception," *Proc., DARPA Image Understanding Workshop*, Washington, D.C., June 1983.

Extends previous work in connectionist form perception to deal with many additional concepts, including image noise, patterns, moving shapes, space-time issues, and hierarchical shape representation. (An early version of some of the topics appeared in the *IEEE Computer Vision Workshop*, Ringe, NH, 1982.)

Ballard, D.H., G.E. Hinton, and T.J. Sejnowski, "Parallel visual computation," *Nature 306*, 5938, 21-26, 3 November 1983.

An overview of work at several labs.

Brown, C.M., "Computer vision and natural constraints," *Science 224*, 4655, 1299-1305, 22 June 1984.

Tutorial and introduction to current ideas behind computer vision systems. Has faint connectionist bias.

Ballard, D.H., A. Bandyopadhyay, J. Sullins, and H. Tanaka, "A connectionist polyhedral model of extrapersonal space," *Proc., IEEE Conference on Computer Vision*, Annapolis, MD, 1984.

Working out the details of spatial visual perception in connectionist terms.

Feldman, J.A., "A functional model of vision and space," *Workshop on Vision, Brain, and Cooperative Computation*, U. Mass., Amherst, May 1983. (Book: M. Arbib and A. Hanson (Eds), *Vision, Brain, and Cooperative Computation*, to appear, 1985.)

This is a much reduced version of TR 99, with explicit links to other papers in the book.

Plaut, D.C., "Visual recognition of simple objects by a connection network," Senior thesis and TR 143, Computer Science Dept., U. Rochester, August 1984.

This technical report exhibits a detailed connectionist solution to a technical problem in the Four Frames model (*Behavioral and Brain Sciences*). Indexing (categorization) in that model works in parallel, but can be confused by scrambled images. This paper describes a sequential verification algorithm that prevents these confusions, using techniques similar to those of Hrechanyk and Ballard.

Ballard, D.H. and H. Tanaka, "Transformational form perception in 3d: constraints, algorithms, implementation," *Proc., 9th Int'l. Joint Conf. on Artificial Intelligence*, Los Angeles, CA, August, 1985.

The view transform method extended to polyhedra.

Ballard, D.H., "Form perception as transformation," TR 148, Computer Science Dept., U. Rochester, September 1985.

This is an expanded version of the conference paper by Ballard and Tanaka (above).

Sullins, J., "Value cell encoding strategies," TR 165, Computer Science Dept., U. Rochester, August 1985.

This technical report is a critique and analysis of coarse coding.

Feldman, J.A., "Connectionist models and parallelism in high level vision. TR 146, Computer Science Dept., U. Rochester, January 1985; *CVGIP 31*. Special Issue on Human and Machine Vision, 1985.

A programmatic overview paper, combining technical ideas from several other papers in this section. Suggets an overall design for highly parallel vision systems.

Ballard, D.H. and C.M. Brown, "Vision: biology challenges technology," *BYTE Magazine*, April 1985.

Illustrating the exposition with three examples of current computer vision systems, this article makes two points: parallelism in vision is a necessary future development, and the parallel computations should extend over a hierarchy of representations. Some relevant data from the neurosciences is introduced.

5. Applications to Natural Language

Small, S.L., G.W. Cottrell, and L. Shastri. "Toward connectionist parsing," *Proc., National Conference of the American Association for Artificial Intelligence*, Pittsburgh, PA, August 1982.

This short paper sets forth our initial thoughts on the construction of connectionist models of natural language parsing. Each author worked independently to model the word sense discrimination required to analyze the sentence "A man threw up a ball" using massively distributed networks. The results were put together into this brief description of how a detailed and accurate model of human sentence comprehension might be built.

Cottrell, G.W. and S.L. Small. "A connectionist scheme for modelling word sense disambiguation," TR 122, Computer Science Dept., U. Rochester; *Cognition and Brain Theory* 6, 1, 89-120, 1983.

Cottrell, G.W. and S.L. Small. "Viewing parsing as word sense discrimination: A connectionist approach," in B. Bara and G. Guida (Eds). *Computational Models of Natural Language Processing*. North Holland: Elsevier Science Publishers BV, 1984.

Each of these papers contains an introduction to the problems of connectionist parsing of natural language, and either is a good starting point on the connectionist approach to the computational modeling of natural language comprehension. The papers contend that highly parallel networks are the most fruitful way to go about modeling human language processing. Scientific constraints on such models are presented, along with an initial model that meets many of these constraints. Problems with the existing model and research questions within the overall framework are discussed. The second paper contains material on syntax not included in the first paper.

Small, S.L., "Exploded connections: unchunking schematic knowledge," *Proc., 4th Annual Meeting, Cognitive Science Society*, Ann Arbor, MI, August 1982.

This short paper contains some imprecise thoughts on the exploded nature of human schematic knowledge. It argues that the chunking of knowledge into scripts (frames) may not be the best way to look at the organization of information in a model of human memory, and explains why the connectionist approach might be advantageous for studying memory. Examples illustrate how some classical problems can be looked at differently.

Cottrell, G., "A model of lexical access of ambiguous words," *Proc. National Conference on Artificial Intelligence AAAI*, Austin, TX, August 1984.

A connectionist model of access of information about words which corresponds to current psychological data, explains some anomalies in that data, and makes empirically verifiable predictions.

Cottrell, G., "Re: on inheritance hierarchies with exceptions." *Proc., Workshop on Non-Monotonic Reasoning*, New Paltz, NY, 1984.

Response to Etherington and Reiter's claim that there does not appear to be a way to implement inheritance in semantic networks in parallel. A connectionist inheritance model is described that handles exceptions.

Cottrell, G.W., "A connectionist approach to word sense disambiguation." Ph.D. thesis and TR 154. Computer Science Dept., U. Rochester, May 1985.

Describes a model of parsing in terms of mapping to a case frame representation in connectionist terms. Syntactic and semantic processing proceed in parallel while exerting mutual constraints. This model was developed to conform to recent psychological data on lexical access. Along the way, however, it also served as a basis for an explanation of human parsing preferences, and some recent results concerning agrammatic aphasics. A partial implementation is described. Fanty's parser (below) is a different approach which overcomes some of the problems with the syntactic parser described here.

Cottrell, G.W., "Connectionist parsing," *Proc., 7th Annual Cognitive Science Society Conf.*, Irvine, CA, 1985.

A description of the syntactic parser described in the above thesis.

Cottrell, G.W., "Parallelism in inheritance hierarchies with exceptions," *Proc., 9th Intl Joint Conf on Artificial Intelligence*, 194-202. Los Angeles, CA, August 1985.

A more accessible version of the non-monotonic workshop paper (also described in the thesis).

Cottrell, G.W., "Implications of connectionist parsing for aphasia," *Proc., 9th Annual Symp. on Computer Applications in Medical Care*, Baltimore, MD, 1985.

An updated and improved version of the thesis account of recent neurolinguistic data.

Fanty, M., "Context-free parsing in connectionist networks," TR 174, Computer Science Dept., U. Rochester, November 1985.

This paper presents a simple algorithm which converts any context-free grammar (without ε-productions) into a connectionist network which parses strings (of arbitrary but fixed maximum length) in the language defined by that grammar. The network is fast and deterministic. Some modifications of the network are also explored, including parsing near misses, disambiguating and learning new productions dynamically.

6. Speech Production

Dell, G.S., "Positive feedback in hierarchical connectionist models: applications to language production," Cognitive Science TR 19, Dept. of Psychology, U. Rochester, May 1984; *Cognitive Science*, Special Issue on Connectionism, 1985.

Dell, G.S., "A spreading activation theory of retrieval in sentence production," Cognitive Science TR 21, Dept. of Psychology, U. Rochester, October 1984; to appear, *Psychological Review*, 1986.

Both of these papers present aspects of a connectionist model of human sentence production. The model attempts to explain how words and their sounds are retrieved, ordered, and organized for articulation. The first paper focuses on the role of positive feedback (e.g., phonemes-to-words) in creating, and sometimes preventing, speech errors. The second paper presents the details of the model along with experimental tests of the model's predictions.

7. Motor Control

Addanki, S., "A connectionist approach to motor control," Ph.D. thesis, Computer Science Dept., U. Rochester, 1983.

An analysis of connectionism as a computational paradigm for the analysis and synthesis of control systems. (Available from the author at: IBM T.J. Watson Research Center, P.O. Box 218, Yorktown Heights, NY, 10598.)

Ballard, D.H., "Task frames in robot manipulation," *Proc., National Conference on Artificial Intelligence*, Austin, TX, August 1984.

Hierarchical representation of spatial and mechanical information for robot manipulation.

Ballard, D.H., "Task frames in visuo-motor coordination," *Proc., 3rd IEEE Workshop on Computer Vision: Representation and Control*, Bellaire, MI, October 1985.

Relates vision and motor control through invariants.

Mukerjee, A. and D.H. Ballard, "Self-calibration in robot manipulators," *Proc., IEEE Conf. on Robotics and Automation*, March 1985.

Motor control systems can be self-calibrating.

8. Knowledge Representation and Inference

Ballard, D.H. and P.J. Hayes, "Parallel logical inference," *Proc., 6th Cognitive Science Conference*, Boulder, CO, June 1984.

Ballard, D.H. and P.J. Hayes, "Parallel logical inference and energy minimization," TR 142, Computer Science Dept., U. Rochester, November 1985.

The first paper develops a completely parallel connectionist inference mechanism. The mechanism handles obvious inferences, where each clause is only used once, but may be extendable to harder cases. The second paper contains proof of correctness for some of the ideas in the earlier paper.

Shastri, L. and J.A. Feldman, "Semantic networks and neural nets," TR 131, Computer Science Dept., U. Rochester, June 1984.

Connected networks of nodes representing conceptual knowledge are widely employed in artificial intelligence and cognitive science. This report describes a direct way of realizing these semantic networks with neuron-like computing units. The proposed framework appears to offer several advantages over previous work. It obviates the need for a centralized knowledge base interpreter, thereby partially solving the problem of computational effectiveness, and also embodies an evidential semantics for knowledge that provides a natural treatment of defaults, exceptions, and "inconsistent" or conflicting information. The model employs a class of inference that may be characterized as working with a set of competing hypotheses, gathering evidence for each hypothesis, and selecting the best among these. The resulting system has been simulated and is capable of supporting existing semantic network applications dealing with problems of recognition and recall in a uniform manner.

Shastri, L. and J.A. Feldman, "Neural nets, routines, and semantic networks," in N.E. Sharkey (Ed), *Advances in Cognitive Science*. Ellis Horwood, Pub., to appear, 1986.

This is an updated version of TR 131 minus implementation details. The more recent semantic network papers (IJCAI, Shastri thesis (below)) take a somewhat different tack.

Feldman, J.A. and L. Shastri, "Evidential inference in activation networks," *Proc., 6th Cognitive Science Conference*, Boulder, CO, June 1984.

A very reduced version of TR 131 that is intended to allow people to assess whether they want to approach the full paper.

Shastri, L., "Evidential reasoning in semantic networks: a formal theory and its parallel implementation," Ph.D. thesis and TR 166, Computer Science Dept., U. Rochester, September 1985.

This thesis describes an evidential framework for representing conceptual knowledge, wherein the principle of maximum entropy is applied to deal with uncertainty and incompleteness. It is demonstrated that the proposed framework offers a uniform treatment of inheritance and categorization, and solves an interesting class of inheritance and categorization problems, including those that involve exceptions, multiple hierarchies, and conflicting information. The proposed framework can be encoded as an interpreter-free, massively parallel (connectionist) network that can solve the inheritance and categorization problems in time proportional to the depth of the conceptual hierarchy.

Shastri, L. and J.A. Feldman, "Evidential reasoning in semantic networks: a formal theory," *Proc., 9th Intl. Joint Conf. on Artificial Intelligence*, 465-474, Los Angeles, CA, August 1985.

Excerpted from Shastri's thesis (TR 166) with emphasis on evidential inference.

9. Simulation

Sabbah, D., "A connectionist approach to visual recognition." TR 107 and Ph.D. thesis, Computer Science Dept., U. Rochester, April 1982.

> Our first large program in the connectionist paradigm. It simulates a multi-layer network for recognizing line drawings of Origami figures. The program successfully deals with noise and simple occlusion and the thesis incorporates many key ideas on designing and running large models.

Small, S.L., L. Shastri, M.L. Brucks, S.G. Kaufman, G.W. Cottrell, and S. Addanki, "ISCON: A network construction aid and simulator for connectionist models." TR 109. Computer Science Dept., U. Rochester, April 1983.

> This paper describes the organization and use of the connectionist network construction and simulation program that currently runs in Franz Lisp on our Vax 780 under Unix. The program (ISCON) aids the user in building connection networks and then simulating their activity with graphical illustration. The user and the program interact to build up networks that would be complicated to do by hand; simple ISCON commands cause some complex (but schematic) connection network patterns to be incorporated at particular points in the user's network design. During the last two years, this work has been substantially extended to simulators running in other languages and on the Butterfly multiprocessor (see [Fanty, 1985], below).

Fanty, M., "A connectionist simulator for the Butterfly," TR 164, Computer Science Dept., U. Rochester, to appear, January 1986.

> This paper details the implementation of a connectionist simulator on the BBN Butterfly Multiprocessor. The simulator runs on 128 processors concurrently with up to 128 Megabytes of memory, and shows nearly linear speedup on sufficiently large problems.

10. Hough Transform Developments

Brown, C.M., "Bias and noise in the Hough transform I: Theory," TR 105, Computer Science Dept., U. Rochester, June 1982; appeared as "Inherent bias and noise in the Hough transform," *IEEE Trans. on Pattern Analysis and Machine Intelligence* 5, 6, 493-505, September 1983.

Analytic study of shapes of peaks in HT accumulator space. Contributes to a general theory of Hough transform performance.

Brown, C.M. and D.B. Sher, "Hough transformation into cache accumulators: Considerations and simulations," TR 114, Computer Science Dept., U. Rochester, August 1982; a superset of "Modeling sequential behavior of Hough transform schemes," *Proc., DARPA Image Understanding Workshop*, 115-123, Palo Alto, September 1982.

Experimental study of using a small context-addressable cache to accumulate HT votes. Presents a heavily parameterized model and many statistics of its performance in various configurations.

Brown, C.M., M.B. Curtiss, and D.B. Sher, "Advanced Hough transform implementations," *Proc., 8th International Joint Conference on Artificial Intelligence*, Karlsruhe, Germany, August 1983.

A precis of TR 105 and TR 114.

Brown, C.M., "Hierarchical cache accumulators for sequential mode estimation," TR 125, Computer Science Dept., U. Rochester, July 1983.

A quad-tree structure is implemented in a cache hierarchy. Flushing can then be based on properties of volumes of accumulator space.

Sher, D. and A. Tevanian, "The vote tallying chip," *Custom Integrated Circuit Conference*, Rochester, NY, May 1984.

Description of a VLSI circuit that implements content-addressable cache for use as accumulator cache in Hough transform.

Brown, C.M., "Peak-finding with limited hierarchical memory," *Proc., 7th Int'l. Conf. on Pattern Recognition*, Montreal, August 1984.

Presents a cache-flushing scheme that uses information about the vote distribution to increase the reliability of peak-finding algorithms.

Brown, C.M., "Mode estimation with small samples and unordered bins," TR 138, Computer Science Dept., U. Rochester, June 1984.

Combinatorial investigation of peak-finding with *no* information about the underlying distribution. Analytical results are resistant to approximation so simulations provide the practical results.

11. Theory

Ballard, D.H. , P.C. Gardner, and M. Srinivas. "Graph problems and connectionist architectures," TR 167. Computer Science Dept., U. Rochester, December 1985.

This paper addresses several issues related to energy minimization algorithms. It shows techniques for reducing graph problems to energy minimization, and demonstrates proofs of correctness for a binary machine model. It also provides a model for the asynchronous updating of units in the binary machine.

Ballard, D.H., "Value unit interpolation: a receptive field model," TR 175. Computer Science Dept., U. Rochester, January 1986.

Connectionist models of the cortex use discrete units to represent numerical quantities. These have been termed value units. A problem with such an encoding is that there has not been a way to interpolate accurate numerical quantities using the discrete units. This paper remedies the deficiency by describing an interpolation scheme. The scheme has nice properties: it extends across functional mappings and it allows different sources of evidence to be combined.

Appendix A: Errata Sheet for "Dynamic Connections in Neural Networks," by J.Feldman

ERRATA

Figure 4 (p. 31), Figure 7 (p. 33), and Figure 8 (p. 35) are incomplete as published. The correct versions of these Figures appear below and overleaf. In addition there are the following typographical errors.

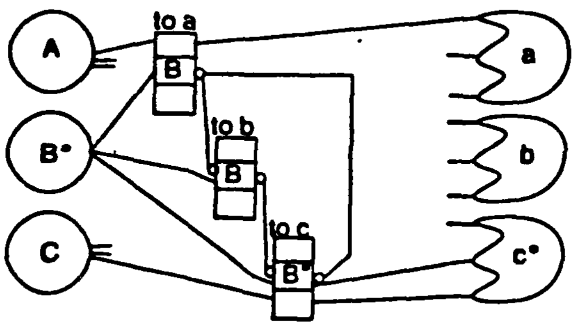
p. 28, second column, line 11, should read 'v ← if p > 0 ...'

p. 30, second column, line -13, should read 'stimulate *A* and *not B*.'

p. 33, line -10, formula should be $\overline{P} = (1\text{-}F)^{B^K}$.

p. 35, line -12, formula should be 'v ← .2p'

p. 36, line 16, formula should be 'Pr(*k* links) = $\binom{d}{k}$ ...'



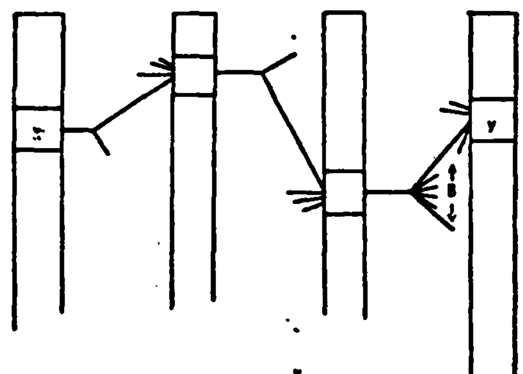
Inter-unit

	One-end	Dual	Block	—
Idle	Low	High / Block	Blocked	
Low	High / Block	High / Block	Blocked	Idle
High	(Low)		X	Low
Blocked		X		Idle

End-unit

	Start	From inter	—
Idle	Low	Low	
Low	High	High	Idle
High		(Low)	Low

Figure 4 State and output tables for dynamic connections



$\overline{P} = (1-F)^{B^K}$

$\overline{P}$ = Probability that there is <u>no</u> link from x to y
N = Number of Units in a "Layer"
B = Number of Randomly Outgoing Branches/Unit ≪ $\sqrt{N}$
F = B/N (Branching Factor)
K = Number of Intermediate Levels (2 in diagram above)

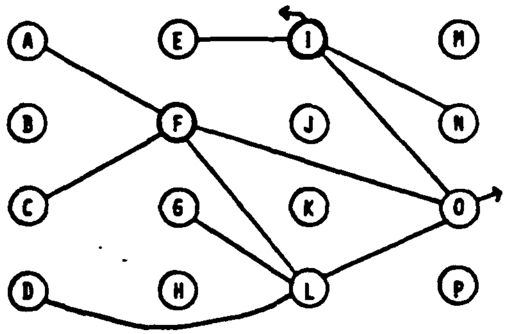
$\overline{P}$ for B = 1000; different numbers of levels and units

K= \ N=	10^6	10^7	10^8
0	.999	.9999	.99999
1	.367	.905	.989
2	10^{-440}	10^{-44}	10^{-5}

Figure 7: Making a connection.

Random Networks:

N nodes each connected to $\sqrt{N}$ others



Assume $v = .2 *$ potential; Decay is 2

	F	I	G	L	O	A	N	. . .
T = 0								
1	10	10	0	0	0	0	0	
2	10	10	0	2	4	2	2	
3	10	10	0	2.8	6	2	2	
4	10	10	1	4	8.6	2	2	
5	10	10	1	6.3	10	2	2	

Figure 8: Random Chunking Network